Clean Energy and Sustainable Development lab
Workshop 2015

New technologies in photovoltaic technology: electrical energy production from vertical walls

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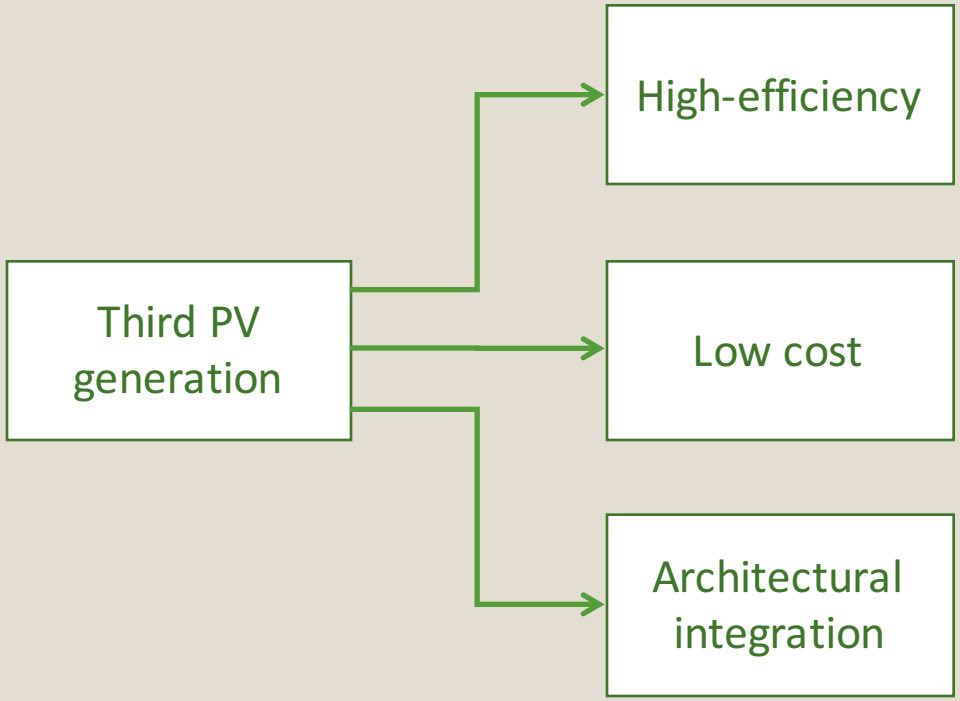
OUTLINE

- Introduction
- Structures
- Experimental measurements
- Cost of Systems
- Comparative analysis of systems
- Conclusions

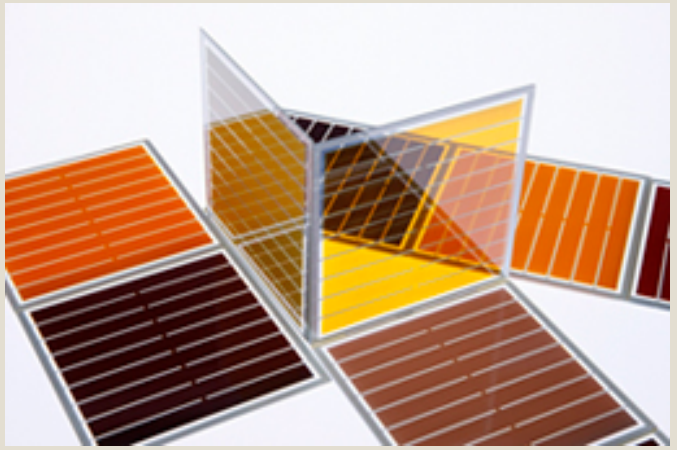
INTRODUCTION



Among these innovative technologies, the solar cells based on semiconductors with a nano-crystalline structure and hybrid organic–inorganic dyes seem the most promising.

These cells are identified as dye-sensitized solar cell (DSSC).

INTRODUCTION



The use of the DSSC cells allow to:

- PV systems with different colors
- the glass module structure with various degrees of transparency
- systems with a high potential for architecturally integrated applications

Moreover, this technology convert into electricity the light coming from both outside and indoor environments.

The aim of this paper is to evaluate the performance and the behavior of the innovative systems, which favor architectonical integration, and trace-out the economic advantages.

Three different systems have been taken into account: a dye sensitized solar cell (DSSC), blue and grey caved silicon panels.

STRUCTURES: Vertical glass wall

External view of vertical glass wall

Inside view of vertical glass wall

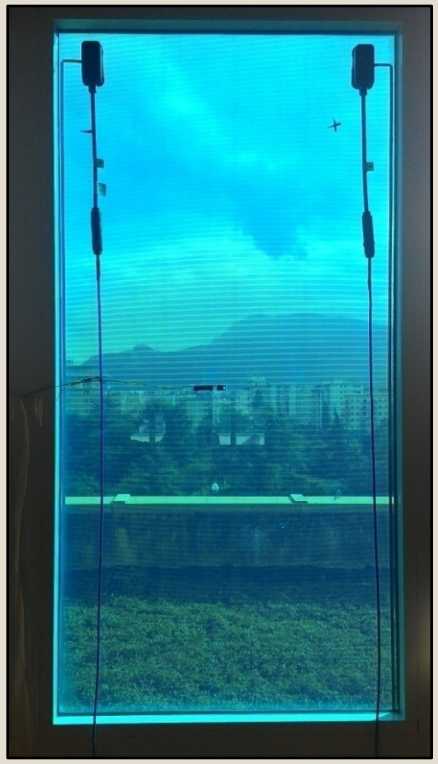
The first structure under study is the vertical glass wall.
For this structures there are three different generation systems have been developed: one DSSC and two silicon dug panels.

Window with integrated PV systems have dimension 1200mm per 600 mm.

The transparency degree varies from dark (opaque) to a conventional 40%.

STRUCTURES: Vertical glass wall

Particular of laminated silicon grey



Particular of laminated silicon blue

The technique used to make the transparent silicon consist in removing the active material so as the degree of transparency increases.

The maximum power of a windows varies from 45 Wp to 20 Wp depending on the degree of transparency.

Open circuit voltage has a constant value 58 V, only current varies with transparency short circuit current varies from 1.07 A to 0.54 A.

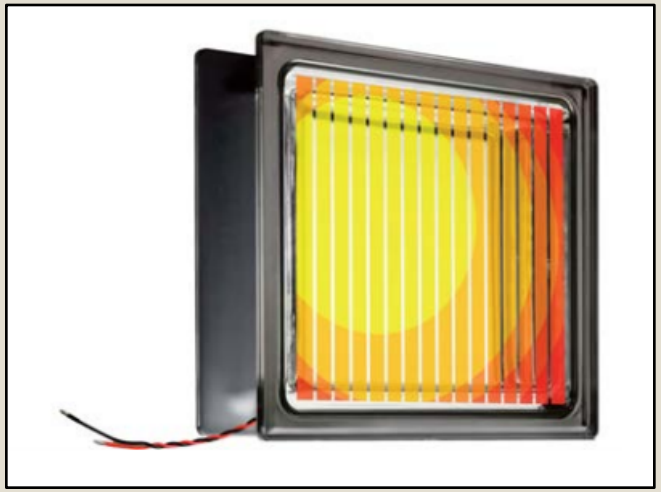
STRUCTURES: Vertical glass wall

Particular of DSSC system

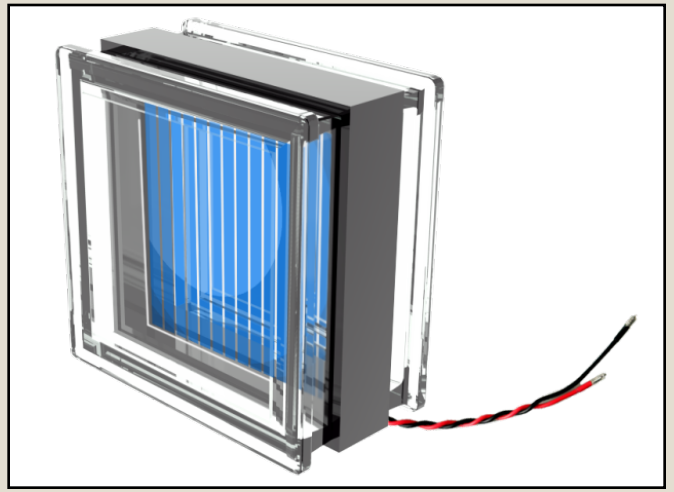
The DSSC panel has an eight sub-panels and connected in series.

By considering a morning in which the irradiance was 709 W/m^2 for horizontal plane, in the vertical system the open circuit voltage is equal to 20 V, and the short circuit current 0.3 A.

STRUCTURES: Glass block wall



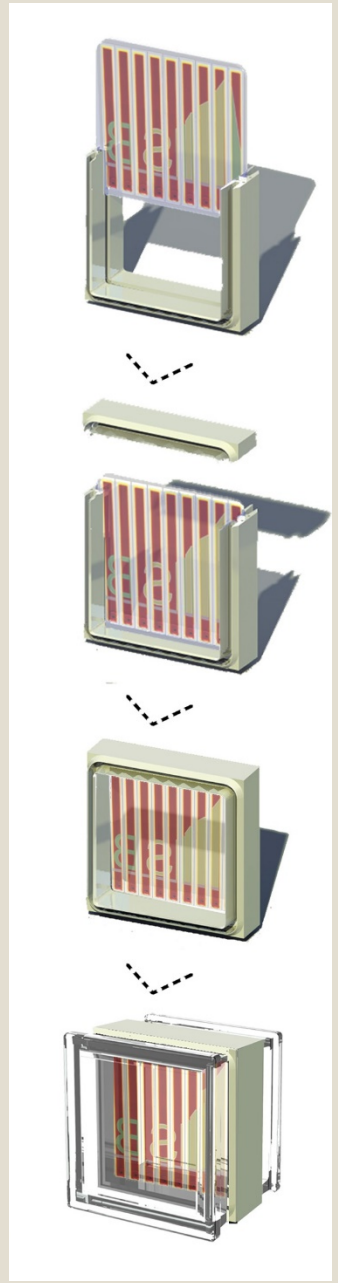
Structure of glass block with DSSC cell



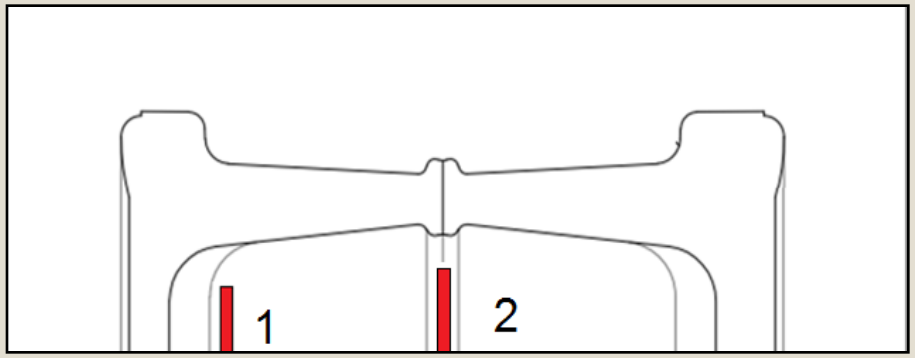
Structure of glass block with Si cell

The structure can be imagined as composed of two shells of transparent glass held together by a frame opaque.

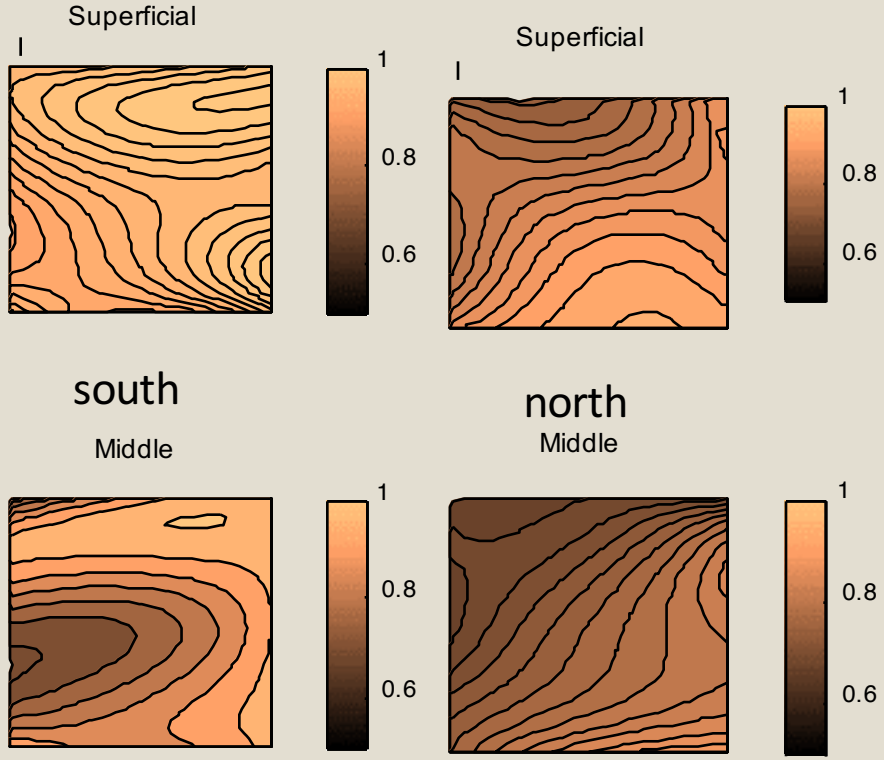
The glass structure has the task of ensuring the mechanical function of the system but also to present the best passage to the light radiation.



STRUCTURES: Glass block wall



Section of the glass block in which the PV cell is red coloured: 1 internal placement on the surface, 2 in the midle section.

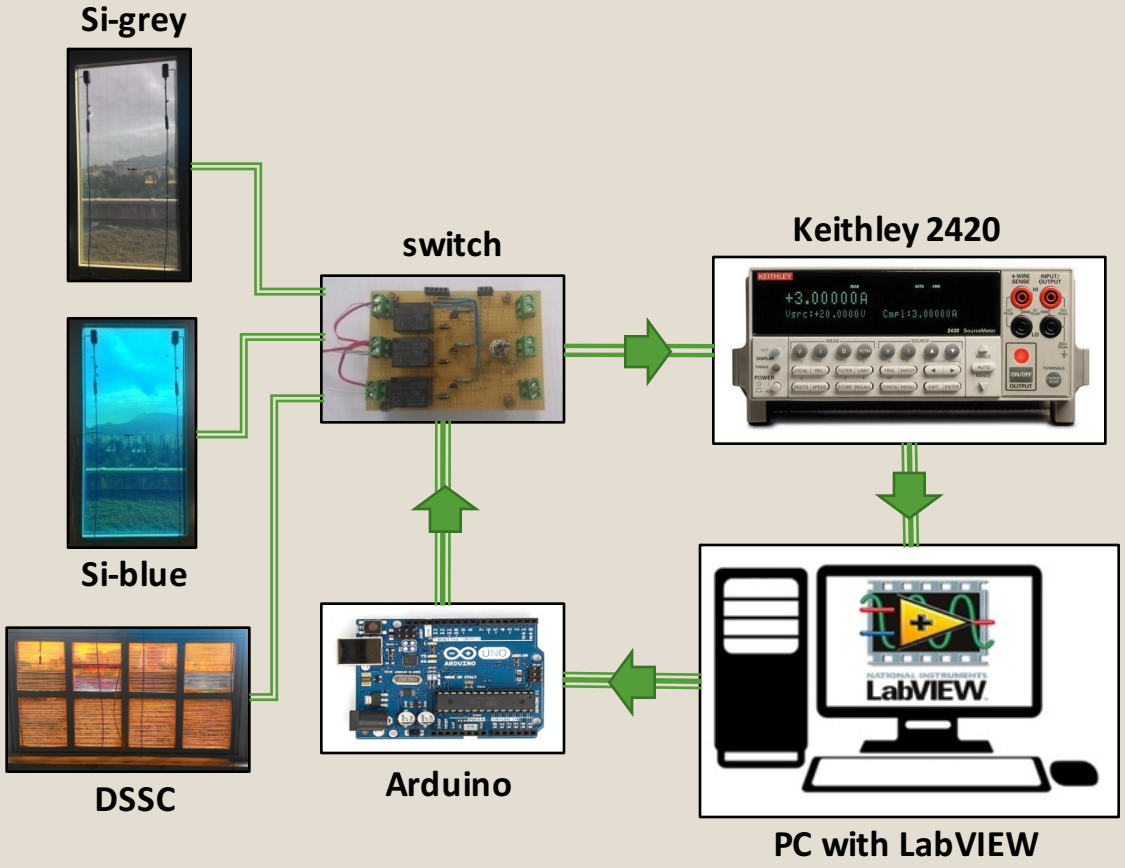


Distribution of daylight in the surface of the glass block, referred to the free space.

The PV cell is fixed in the surface facing the internal environment, in order to protect and maintain it.

By taking into account the radiation in free space and beyond the glass block an average in order of 10% reduction can be evaluated.

EXPERIMENTAL MEASUREMENTS

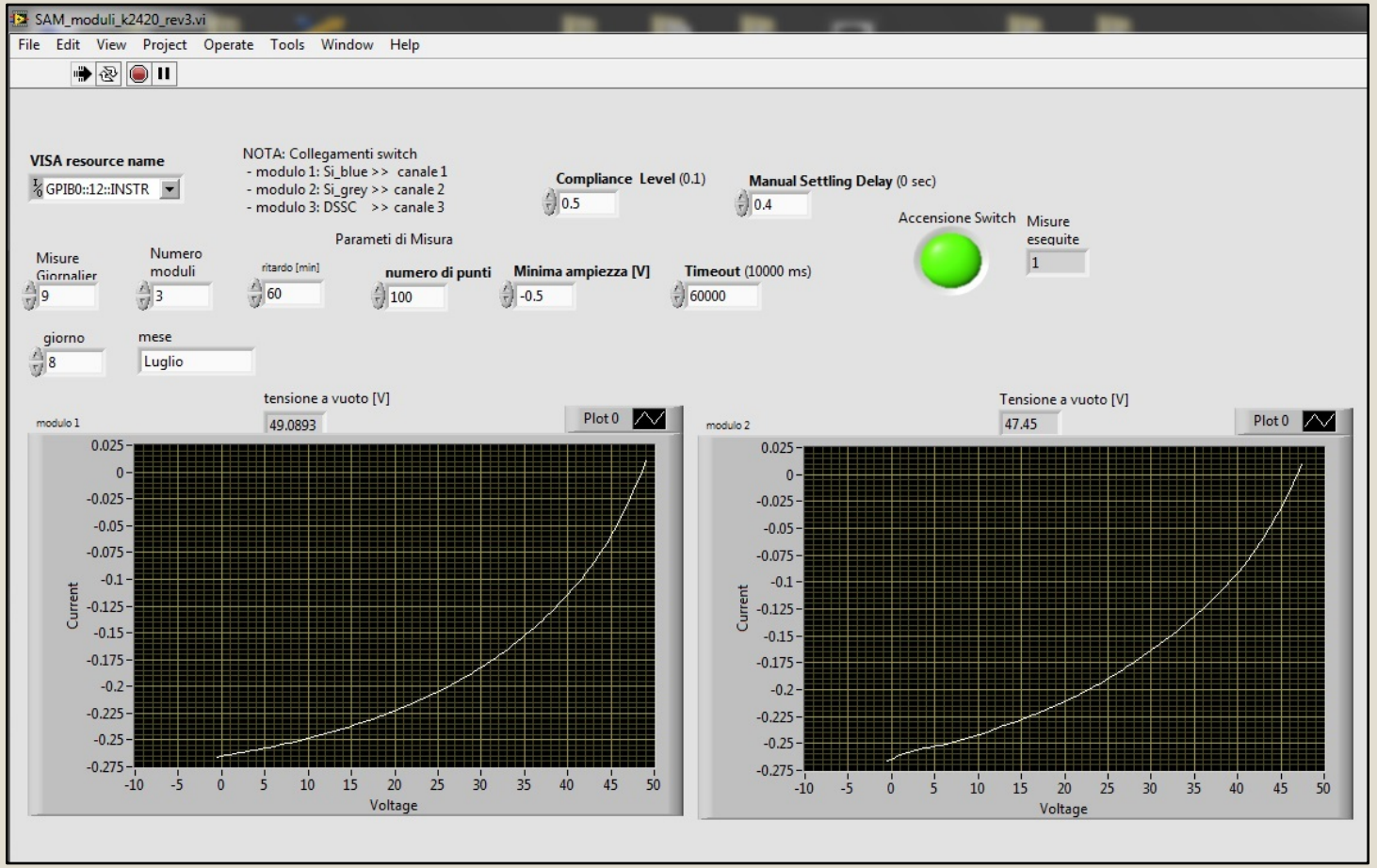


For experimental measurement of electrical values has been realized an automatic measuring system (AMS).

The AMS is composed of:

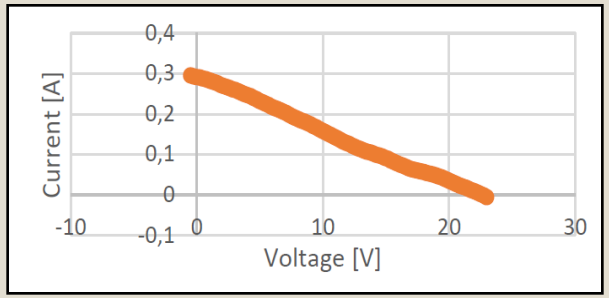
- source meter by keithley model 2420
- personal Computer with labVIEW
- the electronic switch to change the measurement channel
- arduino board to control the switch in real time with labVIEW

EXPERIMENTAL MEASUREMENTS

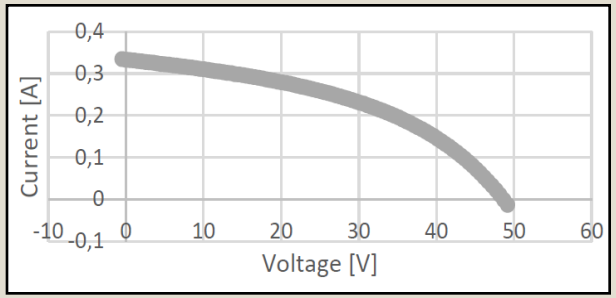


Screenshot of the front panel operating under labview environment

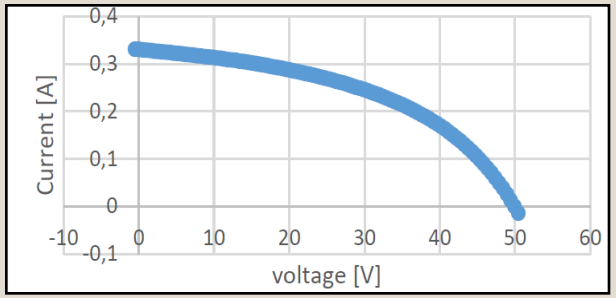
EXPERIMENTAL MEASUREMENTS



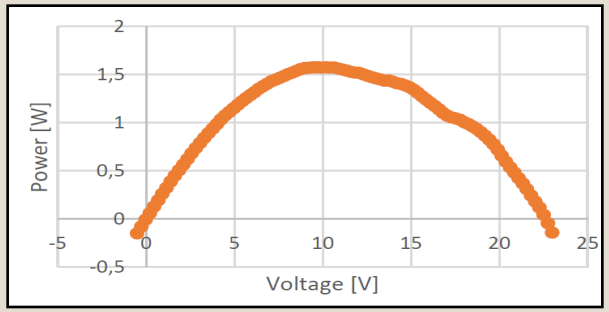
Voltage-current profile of the DSSC vertical system



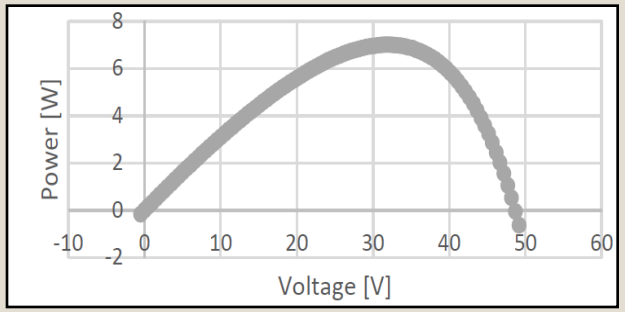
Voltage-current profile of the grey silicon vertical system



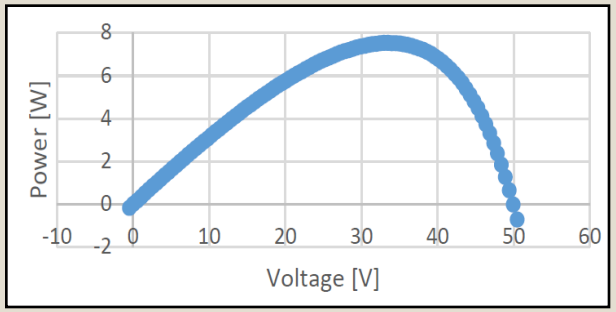
Voltage-current profile of the blue silicon vertical system



Voltage-power profile of the DSSC vertical system



Voltage-power profile of the grey silicon vertical system



Voltage-power profile of the blue silicon vertical system

COST OF SYSTEMS

Tab. I – Cost of systems

	DSSC cell	Silicon Cell
Process of construction	The process of construction of a DSSC is not complicated because the operations to be carried out are simpler and fewer in number and the energy required for hot working is much lower.	The creation of a Silicon cell is more complex because high temperature are required (purification, doping and deposition of the anti-reflection coating). Moreover, is the need an extremely clean inside the working environment.
Industrialization	The production technologies required for DSSC are not fully developed in industrial, so there are no established technologies and energy-efficient process that allow reducing the payback time for any investment.	The technologies of production and processing of silicon are well-established in the industrial (thanks to the industrial electronics development).
Cost of production	Researchers have estimated production costs for DSSC cells. - 2.2 $/ Wp (DSSC Mayer) - 0.8 $/ Wp (DSSC Smestad)	The considered production production cost of a polycrystalline silicon cell. - 1.78 $/Wp

COMPARATIVE ANALYSIS OF SYSTEMS

Tab. II – Comaparative analysis of systems

	Technical literature		Experimental		
	DSSC	**Silicon**	**DSSC**	**Grey**	**Blue**
Efficiency	5%	15%	-	-	-
Vertical Efficiency	2.5%	7.5%	0.31%	1.31%	1.31%
Surface [m^2]	40	13.3	322.6	76.6	76.6
Cost [€]	4068	3273	32806	18740	18740
Glass block [€]	4520	-	36452	20823	20823

For quantitative analysis, a 1.5kWp wall has been taken into account. For the comparison between DSSC, the Mayer cell has been considered, for silicon panel an opaque panel has been taken into account.

The comparative analysis shows that :

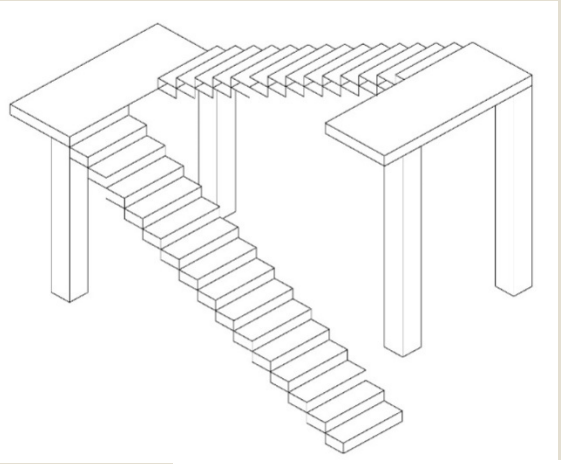
- the cheaper systems is the one created with opaque silicon panel, which cannot be used for a window
- interesting performance is given by the Mayer cell, which cost is near to the traditional opaque panel
- not brilliant performances have been shown by monitored systems, for which efficiency is far from the theoretical
- the use of a glass wall cement slightly increases the costs for the realization of the system

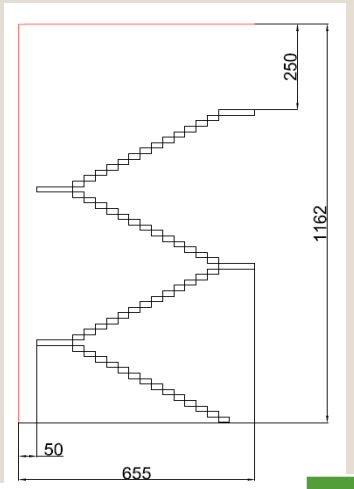
CONCLUSIONS

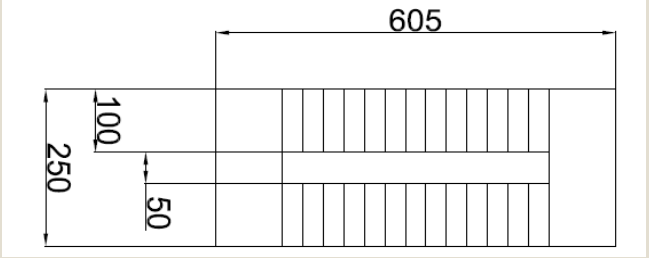
In this work, a comparison between the costs of vertical wall has been traced. Vertical transparent walls, made with DSSC and laminated silicon cells, show costs greater than a traditional vertical PV systems, suggesting that better technologies have to be developed in order to perform a competitive answer to already used tecnologies.

Thanks for your attention

case study: the coverage of an outer scale







- DSSC manage to integrate perfectly with the structure as it has transparency and various colors
- The silicon cell, in contrast, is completely black and without any transparency, completely obscuring the scale of cover and making the structure not very pleasant to the sight
- Laminated silicon panels allow an architectonically integration with the structure

	Technical literature		Experimental		
	DSSC	Silicon	DSSC	Grey	Blue
Vertical efficiency	2.5%	7.5%	0.31%	1.31%	1.31%
Annual decay	5%	0.5%	5%	0.5%	0.5%
Life Years	10	10+	10	10+	10+
Cost €/m²	101.7	245.5	101.7	245.5	245.5
Cost [€]	13409	32367	13409	32367	32367
Power [kW]	9.89	29.6	1.22	5.17	5.17
first year energy [kwh]	6279	18839	778	3290	3290
Energy required [kWh]	9000	9000	9000	9000	9000
First year E sold [kWh]	-2721	9839	-8222	-5709	-5709
NPV [€]	**-11498**	**-15164**	**-13000**	**-30000**	**-30000**

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- Kalyanasundaram, K., Ed., Dye-sensitized solar cells, EPFL Press, Lausanne, ISBN: 978-2-940222-36-0.
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- Viola, F ; Romano, P; Miceli, R; Riva Sanseverino, E; Corrao, R; Morini, M; Pastore. L; Pidanic, J; Perrone, G, Performance of the Glass Block in Photovoltaic Generation, 2015 Tenth International Conference on Ecological Vehicles and Renewable Energies (EVER), Monaco Ever 2015
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